A Tablet for Healthy Ageing: The effect of a tablet computer training intervention on cognitive abilities in older adults

Citation for published version:
Vaportzis, E, Martin, M & Gow, AJ 2017, 'A Tablet for Healthy Ageing: The effect of a tablet computer training intervention on cognitive abilities in older adults', *American Journal of Geriatric Psychiatry*, vol. 25, no. 8, pp. 841-851. https://doi.org/10.1016/j.jagp.2016.11.015

Digital Object Identifier (DOI):
10.1016/j.jagp.2016.11.015

Published In:
American Journal of Geriatric Psychiatry

A Tablet for Healthy Ageing: The Effect of a Tablet Computer Training Intervention on Cognitive Abilities in Older Adults

Eleftheria Vaportzis, Ph.D., Mike Martin, Ph.D., Alan J. Gow, Ph.D.

Objective: *To test the efficacy of a tablet computer training intervention to improve cognitive abilities of older adults.* **Design:** *Prospective randomized controlled trial.* **Setting:** *Community-based aging intervention study, Edinburgh, UK.* **Participants:** *Forty-eight healthy older adults aged 65 to 76 years were recruited at baseline with no or minimal tablet experience; 43 completed follow-up testing.* **Intervention:** *Twenty-two participants attended a weekly 2-hour class for 10 weeks during which they learned how to use a tablet and various applications on it.* **Measurements:** *A battery of cognitive tests from the WAIS-IV measuring the domains of Verbal Comprehension, Perceptual Processing, Working Memory, and Processing Speed, as well as health, psychological, and well-being measures.* **Results:** *A 2 × 2 mixed model ANOVA suggested that the tablet intervention group (N = 22) showed greater improvements in Processing Speed ($\eta^2 = 0.10$) compared with controls (N = 21), but did not differ in Verbal Comprehension, Perceptual Processing, or Working Memory (η^2 ranged from −0.03 to 0.04).* **Conclusions:** *Engagement in a new mentally challenging activity (tablet training) was associated with improved processing speed. Acquiring skills in later life, including those related to adopting new technologies, may therefore have the potential to reduce or delay cognitive changes associated with ageing. It is important to understand how the development of these skills might further facilitate everyday activities, and also improve older adults' quality of life.* (Am J Geriatr Psychiatry 2017; 25:841–851)

Key Words: Cognitive aging, intervention, older adults, tablet computers, technology

For the first time in history, the number of people aged 65 years or older is soon expected to outnumber children under age 5 years.[1] It is important to understand age-related changes in cognitive abilities for both individual and societal reasons. Cognitive decline can compromise the quality of life of older adults and limit their independence.[2] Therefore, effective interventions that might reduce or delay

Received May 16, 2016; revised October 25, 2016; accepted November 23, 2016. From the Department of Psychology, School of Social Sciences (EV, AJG), Heriot-Watt University, Edinburgh, UK; Gerontology Center and University Research Priority Program "Dynamics of Healthy Aging" (MM), University of Zurich, Switzerland; and Centre for Cognitive Ageing and Cognitive Epidemiology (AJG), University of Edinburgh, Edinburgh, UK. Send correspondence and reprint requests to Alan J. Gow, Department of Psychology, School of Social Sciences, Heriot-Watt University, Edinburgh EH14 4AS, UK. e-mail: a.j.gow@hw.ac.uk

http://dx.doi.org/10.1016/j.jagp.2016.11.015

cognitive decline, or indeed lead to improvements in cognitive ability, are critical for the older population, especially those at higher risk of cognitive decline.[3]

Engaging in cognitively demanding tasks has been associated with the maintenance of cognitive abilities—as the popular saying "use it or lose it" implies. The use-it-or-lose it theory also proposes that increases in cognitive activity have the potential to reduce cognitive decline associated with healthy as well as pathological aging.[4,5] To date, there has been a strong focus on cognitive training rather than cognitive engagement. Cognitive training, where an individual is engaged in a focused, repetitive task is usually targeted at improving a specific cognitive ability, though improvements across a range of cognitive abilities, or transfer, would be a key goal. In contrast, participating in activities that involve novel learning experiences and acquiring new skills may simultaneously train a number of cognitive abilities including executive function, reasoning, and memory.[6] Cognitive engagement versus more focused cognitive training may therefore offer opportunities to produce broader benefits.

Support for the benefits of cognitive engagement has come from observational studies that generally report higher participation in cognitively stimulating activities to be associated with better cognitive ability and healthier brain parameters, such as greater gray matter volume[7] and reduced rates of hippocampal atrophy.[8] It is rarely possible, however, to definitively state whether this evidence supports preserved differentiation or differential preservation: Does the cognitive engagement preserve or improve cognitive ability, or is it simply the case that people with higher cognitive ability are more likely to engage with cognitively stimulating activities?[9,10]

The causal pathway is often more clearly articulated in experimental studies, and these have also found cognitive engagement to be beneficial for cognitive function in aging. For example, compared with a control group, participants aged 60–75 years engaged in novel problem solving and creative activities (e.g., creative drawing, logic puzzles, musical activity) for 10–12 weeks showed significant improvement on measures of fluid intelligence.[11] Similarly, in the Senior Odyssey study,[12] participants aged 59–93 years were engaged in group problem-solving competitions that involved various cognitive processes including reasoning and working memory for 20 weeks. At the end of the program, experimental participants showed improved fluid cognitive ability. In the Experience Corps, adults over 60 years (mean: 70.1, SD: 6.4 years) taught classroom behavior, reading skills, and library support to children from kindergarten to third grade.[13] Improvements in executive function and memory were reported at 4, 6, and 8 months. These studies are consistent with the suggestion that increased engagement in cognitively demanding activities might preserve or improve cognitive abilities in older adults.

In the Synapse Project, Park and colleagues[14] randomized older adults (aged 60–90 years) to three engagement groups: learning either quilting, or digital photography, or a combination of both quilting and digital photography. The activities were referred to as "productive engagement" as the tasks were new and cognitively demanding. Two "receptive engagement" groups were also included for comparison, involving familiar activities low on cognitive demand: one social group that engaged in social interactions, trips, and entertainment, and one placebo group that engaged in tasks that were less likely to have cognitive benefits (e.g., listening to music). Participants in the productive engagement groups spent an average of 15 hours per week in the Synapse environment: this time included both formal instruction (5 hours) and completion of course assignments (10 hours). Similarly, individuals in the social group participated for an average of 15 hours per week, comprising common structured activities (5 hours) and additional activities with other members (10 hours). The placebo group made the same time commitment but performed a structured set of activities that required existing knowledge (e.g., watching documentaries, word knowledge games) rather than tasks that represented novel engagement experiences. After the 3-month intervention period, the productive engagement groups (quilting and/or photography) showed significant improvement in episodic memory compared with the receptive engagement groups. Park et al. therefore concluded that learning new skills can improve cognitive ability.

More recently, in an extension of the Synapse Project, Chan and colleagues[15] trained 18 older adults (aged 60–90 years) who were computer novices to use a tablet computer (iPad). Participants attended a tablet training course once a week for 3 months. Cognitive performance was compared with a placebo group that engaged in passive tasks requiring limited new learning, and a social group that had regular social interaction, but no active skill acquisition. As an extension of the Synapse project, participants in the tablet training group spent an average of 15 hours per week in the Synapse environment learning a new set of skills associated with the iPad. Specifically, they completed a 2.5-hour class twice per week and approximately 10 hours of homework assignments. The placebo group made an equivalent time commitment but completed activities that were not cognitively demanding (e.g., watching movies, magazine reading). The tablet group showed improvements in episodic memory and processing speed compared with both control groups; the three groups did not differ on mental control or visuospatial processing.

An advantage of using more lifestyle-based interventions is that the benefits observed may not be limited to cognitive abilities. Tablet training has the potential for sustained cognitive engagement because not only it is a demanding task, but it can also be used to perform daily tasks; therefore, it could increase independence in older age and improve perceived quality of life.[16] The Tablet for Healthy Ageing study therefore aimed to test the efficacy of a tablet training intervention to improve cognitive abilities of older adults. Specifically, we sought to investigate whether engaging with a new mentally challenging activity (i.e., learning how to use a tablet) has cognitive benefits. Following Chan et al.,[15] we recruited participants with minimal or no tablet experience to commit to a 2-hour weekly tablet training course for 10 weeks. The training focused on how to operate the tablets (hardware) and also on using various applications on the tablets (e.g., Google maps, YouTube, etc.). The course was guided by a highly trained instructor, and participants were required to complete homework activities in their own time. In addition to the cognitive outcomes, we collected and analyzed data on health and well-being outcomes to provide results on the efficacy of the intervention, and also to produce a finalized intervention protocol for larger and longer follow-ups. Although we followed Chan et al.,[15] our intention was to develop three specific aspects. Firstly, and most simply, the original study was conducted in the United States; we sought to replicate these findings in a UK sample. For example, according to global digital statistics,[17] people in the UK spend roughly one hour less on the Internet compared with people in the United States, suggesting that technology consumer culture is not the same in the two countries. Secondly, although recognizing the potential offered by the tablet training classes, and indeed how the Synapse research program more broadly represents an important model for cognitive intervention research, we wanted to explore whether a less intensive intervention might also provide cognitive benefits. The current study therefore utilized a similar tablet training protocol within a community-based environment but that required a reduced time commitment, perhaps reflecting the way in which many older adults would engage with new hobbies and interests (i.e., one class per week, with a degree of homework exercises but completed without additional supervision). Finally, some elements of the cognitive test battery in Chan et al.[15] were completed using touchscreen devices (e.g., CANTAB Spatial Working Memory); we wanted to remove this potential confound to ensure that participants in the tablet group did not perform better on tasks post-intervention purely because of improvements in their physical manipulation of devices similar to those on which testing would be completed.

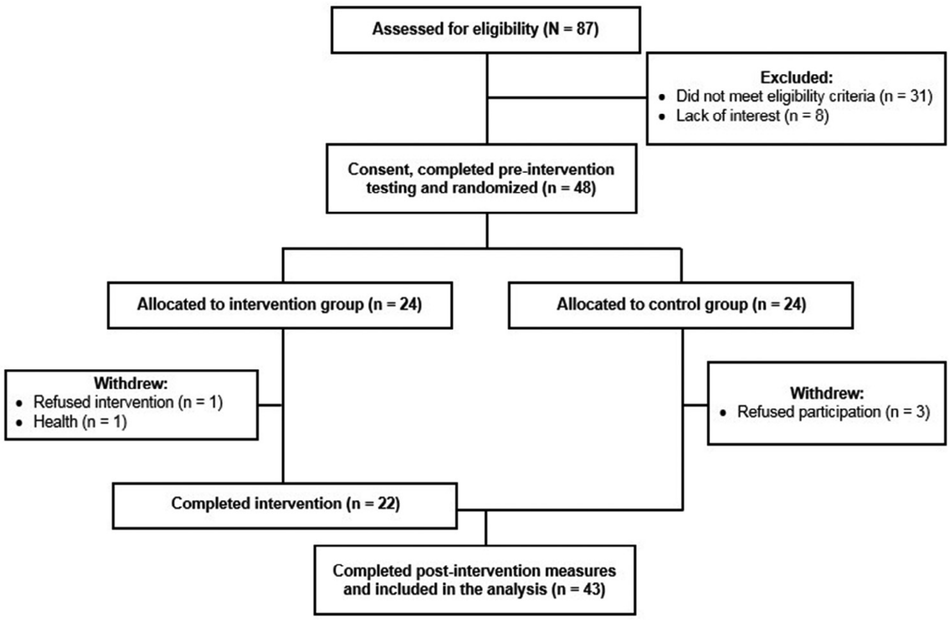
METHODS

Participants

The initial Tablet for Healthy Ageing sample included 48 participants, but 5 participants withdrew from the study (Figure 1). From the tablet intervention group, one participant refused to participate, and one participant could not complete the tablet training course for health reasons. From the control group, three participants refused to return for the second testing session. The final sample included in the analyses therefore comprised 43 relatively healthy, community-dwelling older adults between the ages of 65 and 76 years. There were 22 participants in the tablet intervention group and 21 participants in a no-contact control group.

Participants were recruited from the Edinburgh area by contacting older adult groups and community centers (to display posters, distribute leaflets, or allow a visit from a member of the study team), and by accessing relevant e-mail lists using the snowball principle.[18] All participants were fluent in English, and self-reported that they were free of neurological and psychiatric conditions. For example, participants were asked if they have been diagnosed with a neurological condition such as Parkinson's disease or epilepsy.

FIGURE 1. Consort diagram.



They were also asked if they have been diagnosed with a clinical psychological disorder such as schizophrenia or depression. Participants were excluded if they were younger than 65 years and older than 76 years, if they reported conditions that may affect cognitive function (e.g., dementia), and if they have been tablet users. Most participants had no previous tablet experience, with a few participants having minimal tablet experience (e.g., used a tablet to check e-mails while on holiday). Prior computing experience was not an exclusion criterion, although participants were asked whether or not they had used a computer before, and, if so, how often and what for. The majority of participants reported previous computer use; most used a computer every other day to check e-mails and/or search the Internet.

Participants also completed the Mini-Mental State Examination[19] as a basic screening for potential cognitive impairment, used for descriptive purposes only. A suggested cutoff point for this test is 26 out of 30, indicating potential cognitive impairment. All participants obtained scores over 26 as per the recruitment strategy that was to include only cognitively healthy older adults. Demographic information is presented in Table 1. Ethics approval was granted by the Heriot-Watt University School of Life Sciences ethics committee, this study has thus been performed in accordance with the Declaration of Helsinki.

Assessment Protocol

All participants completed the same assessment protocol within a couple of months pre- and post-intervention. The assessment protocol included the Mini-Mental State Examination,[19] the Hospital Anxiety and Depression Scale,[20] the National Adult Reading Test to assess premorbid intelligence level,[21] the WHO Quality of Life Scale BREF,[22] and the Warwick-Edinburgh Mental Wellbeing Scale[23] to assess aspects of psychological wellbeing, and questionnaires related to sleep patterns, social support, and physical and other activities. The psychological and well-being measures will not be discussed in this report. The cognitive battery included the core subtests from the Wechsler Adult Intelligence Scale, Fourth Edition (WAIS-IV)[24] and was administered by the same researcher (E.V.) who was not involved in the intervention training. A summary of the cognitive ability test battery appears here in order of administration:

TABLE 1. Demographic Variables

	Total	Tablet Group	Control Group	p
N	43	22	21	–
Age, years	69.1 (3.3)	68.4 (3.5)	69.8 (3.0)	$t_{(41)} = 1.34, p = 0.19$
Female %	67.4	71.4	63.6	$\chi^2_{(1)} = 5.23, p = 0.02$
Years of education	14.6 (3.4)	15.3 (3.7)	13.8 (2.9)	$t_{(41)} = -1.45, p = 0.15$
Total program hours	–	94.1 (56.0)	–	––
MMSE pre-intervention	29.2 (0.8)	29.2 (0.9)	29.1 (0.6)	$t_{(41)} = -0.36, p = 0.72$
MMSE post-intervention	28.7 (1.9)	28.6 (0.9)	28.8 (1.4)	$t_{(41)} = 0.47, p = 0.64$
Verbal comprehension pre-intervention	30.4 (6.7)	30.9 (6.3)	29.9 (7.4)	$t_{(41)} = -0.48, p = 0.63$
Verbal comprehension post-intervention	32.4 (6.0)	32.5 (5.2)	32.3 (6.9)	$t_{(41)} = -0.11, p = 0.91$
Perceptual reasoning pre-intervention	31.5 (7.1)	31.4 (7.9)	31.6 (6.3)	$t_{(41)} = 0.95, p = 0.93$
Perceptual reasoning post-intervention	34.0 (8.0)	34.5 (8.2)	33.5 (7.9)	$t_{(41)} = -0.40, p = 0.69$
Working memory pre-intervention	21.5 (4.9)	21.5 (5.8)	21.6 (3.7)	$t_{(41)} = 0.78, p = 0.94$
Working memory post-intervention	22.4 (5.7)	22.0 (5.7)	22.9 (5.9)	$t_{(41)} = 0.24, p = 0.81$
Processing speed pre-intervention	14.5 (2.5)	13.9 (2.3)	15.1 (2.5)	$t_{(41)} = 1.59, p = 0.12$
Processing speed post-intervention	15.2 (2.8)	15.2 (3.1)	15.2 (2.7)	$t_{(41)} = 0.10, p = 0.94$

Notes: Possible range of scores for verbal comprehension and perceptual reasoning was 3–57, and for working memory and processing speed was 2–38. Higher scores indicate better performance. Mean differences were tested with independent t tests for continuous variables, and with χ^2 tests for categorical variables. Standard deviation in parentheses. MMSE: Mini-Mental State Examination.

1. Block Design provides a measure of visual processing. Working within a specified time limit, the participant views a picture and uses red-and-white blocks to recreate the design. The maximum raw score is 66.
2. Similarities provides a measure of crystallized knowledge and fluid reasoning. The participant is presented two words that represent common objects or concepts and describes how they are similar. The maximum raw score is 36.
3. Digit Span provides a measure of short-term memory. It comprises three subtests. For Digit Span Forward, the participant is read a sequence of numbers and recalls the numbers in the same order. For Digit Span Backward, the participant is read a sequence of numbers and recalls the numbers in reverse order. For Digit Span Sequencing, the participant is read a sequence of numbers and recalls the numbers in ascending order. The maximum raw score is 16.
4. Matrix Reasoning provides a measure of fluid reasoning. The participant views an incomplete matrix or series and selects the response option that completes the matrix or series. The maximum raw score is 26.
5. Vocabulary provides a measure of crystallized knowledge. The participant defines words that are presented visually and orally. The maximum raw score is 57.
6. Arithmetic provides a measure of fluid reasoning, short-term memory, and quantitative knowledge. Working within a specified time limit, the participant mentally solves a series of arithmetic problems. The maximum raw score is 22.
7. Symbol Search provides a measure of processing speed. Working within a specified time limit, the participant scans a search group and indicates whether one of the symbols in the target group matches. The maximum raw score is 60.
8. Visual Puzzles provides a measure of visual processing. Working within a specified time limit, the participant views a completed puzzle and selects three response options that, when combined, reconstruct the puzzle. The maximum raw score is 26.
9. Information provides a measure of crystallized knowledge. The participant answers questions that address a broad range of general knowledge topics. The maximum raw score is 26.
10. Coding provides a measure of processing speed. Using a key, the participant copies symbols that are paired with numbers within a specified time limit. The maximum raw score is 135.

Randomization

After baseline assessments, participants were randomly assigned to the intervention (i.e., tablet training) or control group (Figure 1). A computerized block randomization procedure was implemented using www.sealedenvelope.com with a block size of four or six participants. Randomization was stratified by sex. Group allocation was disclosed to participants after all participants completed the pre-intervention testing.

Intervention

The tablet intervention consisted of planned activities that required continuous cognitive challenge by engaging novice tablet computer users in structured lessons and assignments that involved the use of a diverse range of tablet applications. The program was based on Chan et al.,[15] though with updates to ensure applicability to a UK audience and reflect more recent versions of hardware and applications. Before the intervention study, focus group feedback was used to finalize the tablet intervention program (no focus group participants were included in the intervention study). Three focus groups were held to establish older adults' familiarity with tablet computers and similar devices, their exposure to them, and perceived and actual barriers to participation.[25] Focus group outcomes confirmed that the intervention protocols used previously with a sample of healthy older adults in the United States[15] would be appropriate for a UK sample. Therefore, we did not make any major protocol changes for the planned intervention stages.

Participants in the tablet intervention group attended a 2-hour class once a week for 10 consecutive weeks. In addition, they had to complete homework assignments related to the topics covered in class, and they were encouraged to use the tablets as much as possible. The participants were asked to log their tablet usage every day for the duration of the intervention.

All classes were taught by the same instructor and the activities followed a detailed curriculum. The classes included 5–10 participants in each. The first week of classes focused on learning the functions of the Apple iPad Mini 2 (e.g., settings, buttons) and discovering the variety of applications available. Following weeks were organized by theme. For example, for one theme, "Travelling", participants learned how to navigate and find travel apps and local resources apps. For another theme, "Entertainment", they learned how to access music, movies, health and fitness apps, YouTube, and so forth.

Statistical Analysis

Cognitive Ability Domains

We created four cognitive ability domains following the WAIS-IV[24] instructions. Briefly, total raw scores for each of the cognitive tests were scaled for each participant based on the participant's age as determined in the Calculation of Participant's Age tables in the WAIS-IV[24] instructions. The WAIS-IV has been standardized on a large sample of people between the ages of 16 to 90 years in the United States. Then, the sum of scaled scores on specific tests created each of the ability domains (Verbal Comprehension, Perceptual Processing, Working Memory, and Processing Speed). Following Ball et al.[26] and Chan et al.,[15] we created a normalized distribution of the target dependent variables from each measure by pooling together pre- and post-test scores, and then applied a Blom transformation.[27] A composite score for each ability domain was created by averaging the transformed scores associated with each ability domain. We calculated Cronbach's alpha (α) to test the internal consistency and estimate the reliability of each of the ability domains. All ability domains showed good internal consistency, as presented in Table S1.

To investigate the effect of the tablet intervention on cognitive performance, we conducted a 2×2 mixed model ANOVA with the between-factor Group (intervention versus controls) and within-factor Time (pretest versus post-test) for each of the four ability domains separately. For all analyses we examined main effects and two-way interactions. Significant interactions were followed up with pairwise comparisons. Where the two-way interactions were not significant, these were removed and the analyses were repeated including only the main effects. We ran independent measures t tests to look at group main effects, and dependent measures t tests to look at time effects. A Bonferroni adjustment was applied. Alpha was set at 0.05. The amount of time spent doing homework and using the tablet was included as a covariate in the analyses, but it was not found to be significant and did not change the overall findings across the four cognitive domains. Thus, we report analyses without time spent on the tablet as a covariate.

Following Ball et al.[26] and Chan et al.,[15] we also calculated the net effect size for each of the groups. Data were standardized by pooling scores at each time point

TABLE 2. Pre-test and Post-test Cognitive Ability Domain Scores, and Pre-test t Tests

		Groups		Pre-test t test	
Cognitive Ability Domain	Time	Tablet Group	Control Group	t	p
Verbal comprehension	Pre	0.09 (0.9)	−0.02 (1.1)	−0.344	0.73
	Post	−0.01 (0.8)	0.01 (1.1)		
Perceptual reasoning	Pre	−0.02 (1.1)	0.11 (0.9)	0.436	0.66
	Post	−0.01 (1.0)	0.02 (1.0)		
Working memory	Pre	−0.01 (1.1)	0.14 (0.8)	0.506	0.62
	Post	−0.07 (1.0)	0.08 (1.0)		
Processing speed	Pre	−0.18 (0.9)	0.29 (0.9)	1.754	0.09
	Post	−0.04 (1.1)	0.05 (0.8)		

Notes: Mean Blom-transformed score (SD). df = 41.

and applying a Blom transformation.[27] The net effect is defined as the gain in performance (from pre-test to post-test) normalized by the sample's pre-test variance using the formula:

$$\frac{\left(B_i^{post} - B_p^{post}\right) - \left(B_i^{pre} - B_p^{pre}\right)}{s^{pre}}$$

B_i^{pre} and B_i^{post} represent the mean pre- and post-Blom transformation scores for the tablet intervention group, B_p^{pre} and B_p^{post} represent the mean pre- and post-Blom transformation scores for the control group, and s^{pre} is the sample standard deviation at pre-test.

RESULTS

From the logs, participants in the tablet intervention spent on average 1.29 hours per day (SD = 0.8) using their tablet. This time included class attendance, and also homework completion and personal usage of the tablet.

Analysis suggested that the tablet group did not significantly differ from the control group across the four ability domains when recruited at baseline. Table 2 presents the pre-test t test analysis as well as the means and standard deviations (SD) of the Blom transformed scores on the four cognitive ability domains pre- and post-test. A 2 × 2 ANOVA was conducted to investigate group differences across time. From pre- to post-test, the ANOVA results suggested greater improvement in the tablet intervention group compared with the control group on processing speed. Specifically, the overall ANOVA on processing speed revealed a significant main effect of Time ($F_{(1,41)} = 5.88$, $p = 0.02$, $\eta^2 = 0.13$) and a Group × Time interaction ($F_{(1,41)} = 4.36$, $p < 0.05$, $\eta^2 = 0.10$). Follow-up comparisons suggested that the tablet intervention group showed a significant improvement in processing speed performance over time ($p = 0.002$), whereas there was no significant difference in performance for the control group ($p = 0.815$). We note that although not significantly different pre-intervention, the tablet group had slower processing speed compared with controls. Post-intervention, the tablet group significantly improved, but the control group did not show any changes. We also found a significant main effect of Time for verbal comprehension ($t_{(42)} = -3.63$, $p = 0.001$, $d = -0.31$) and perceptual reasoning ($t_{(42)} = 14.43$, $p < 0.001$, $d = -0.33$). We found no other significant main effects or interactions in any of the other cognitive domains (all $p > 0.05$).

Supplementing the ANOVA results, the net effect sizes were congruent with the statistical analysis. The net effect sizes for the four ability domains with group contrasts were: Verbal Comprehension: 0.01, Perceptual Reasoning: 0.04, Working Memory: −0.03, and Processing Speed: 0.10. The only significant effect, albeit small, was observed for Processing Speed. The mean normalized gains scores for all four ability domains between the two groups are presented in Figure 2. In addition, to further elucidate the intervention effects that we found in the tablet group for Processing Speed, individual gain scores for each participant as a function of Group are presented in Figure 3.

DISCUSSION

Participation in a tablet computer training intervention improved performance on one cognitive ability domain, Processing Speed, compared with a no-contact control group. The Tablet for Healthy Ageing results suggest that cognitive engagement, which involves learning new activities and acquiring new skills, may benefit Processing Speed, and indeed that this may be observable before other cognitive domains. This is of particular relevance within the field given the large body of evidence suggesting that processing speed has a major role in mediating relations between age and cognition.[28] Processing Speed is among the most age-sensitive of the cognitive domains, as it is affected early in the aging process, and has therefore been proposed as the most amenable to intervention. Despite that, the effect on processing speed in the current study was small, and this may partly reflect our intention of using a less-intensive version of an intervention previously shown to benefit both processing speed and episodic memory.[15] The small effect size may therefore be partly attributable to the time on task, but other aspects of the study also need to be considered, including the overall length of the intervention period and the initial cognitive status of the participants. Although some individuals in the control group also experienced some cognitive gains in Processing Speed, the tablet intervention group showed significantly greater gains over time. This is illustrated in Figure 3, where the number of bars over 0 was higher in the tablet group compared with the control group, suggesting that more participants in the tablet group showed cognitive gains in Processing Speed. Some cognitive gains in both groups could be due to repeated testing effects.

As it is clear that even healthy older adults experience age-related cognitive decline to some extent,[29] interventions that improve or at least maintain cognitive function in older people are necessary, not only to minimize the impact of cognitive aging but also to enhance quality of life and preserve independence. The findings of this study are consistent with previous research suggesting that engaging in new mentally challenging activities can improve cognitive function.[13–15] More specifically, the significant improvements in Processing Speed in the tablet intervention group compared with the control group are consistent with Chan et al.,[15] supporting the validity of the original study. Chan et al. also reported significant improvements in episodic memory in their tablet

FIGURE 2. Mean standardized gain scores for the tablet and control groups. Standard error bars are included.

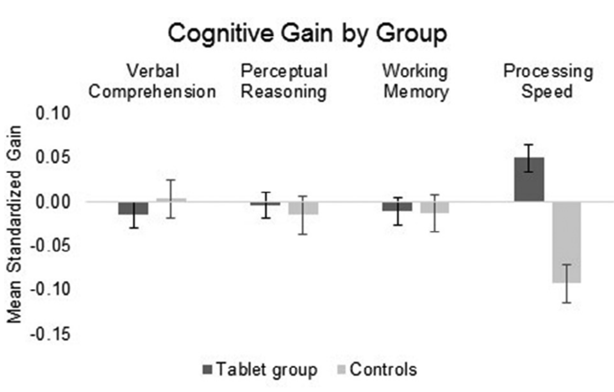


FIGURE 3. Individual gain scores for processing speed for the tablet and control groups.

intervention group. Although we did not replicate a memory benefit, we focused on a different aspect of memory, specifically, working memory. In addition, our intervention was not as intensive and monitored as the intervention used in Chan et al., in which participants were able to attend a drop-in center out of their scheduled classes for continued engagement and support. In the Tablet for Healthy Ageing study, other than their weekly 2-hour class, participants completed all further engagement with their learning independently, which may be reflected in the smaller effect size that was observed. As we specifically sought to have a less-intensive intervention than had been reported previously,[15] the lower effect sizes reported are not unexpected. Future studies under the Synapse and Tablet for Healthy Ageing model should therefore seek to manipulate the duration of the intervention and level of engagement to assess potential dose-response effects. For example, level of engagement could be manipulated within a single study by having groups of participants receiving different numbers of hours of class-based instruction per week, and/or completing different amounts of work outside the normal intervention hours, or varying the overall period over which the intervention extends. Another way to compare different levels of engagement would be to vary the support structure of the setting, from the relatively well-supervised Synapse environment in which both the classes and "homework" activities were completed in the same setting, versus settings similar to the Tablet for Healthy Ageing study where only classes were supervised and all homework activities were completed independently and without additional support. We note that the results were unchanged after removing from the analyses a participant who logged zero hours of engaging with their tablet out with the instructor-led classes (i.e., although they attended 80% of the classes they did not report completing any homework activities). All other participants logged at least 28 hours of homework over the duration of the course, with most reporting over 70 hours, suggesting a high level of engagement with the activity.

Another possible explanation for the smaller effect sizes and significant benefit only in Processing Speed may lie in the nature of the tests used in Chan et al.[15] Tasks included pen-and-paper (e.g., Modified Hopkins Verbal Learning Task[30]) as well as computerized tasks (e.g., CANTAB Verbal Recognition Memory[31]) performed on a touchscreen. It is therefore possible that any improvements observed were due to the mechanical aspect of tasks or increased familiarity after the tablet training rather than cognitive changes. Our study overcame this issue by including pen-and-paper and oral tasks. A direction for future studies is to assess how long any cognitive benefits persist post intervention and whether a tablet-based intervention could provide cognitive benefits in individuals that have already experienced mild cognitive decline.

Although we found significant improvements in Processing Speed in the tablet intervention group, the opposite was observed in the control group: Processing Speed performance declined post-intervention in the control group (albeit some individuals did show cognitive gains, as discussed earlier). It is possible that the control group was less motivated to perform the tasks post-intervention as no participation incentive was provided. Participants' lack of motivation may have been reflected more in Processing Speed rather than the other ability domains as Processing Speed was measured using timed tasks only, despite the instructions that emphasized to work as fast as they could without making mistakes. Our tablet training intervention did not target processing speed specifically; nonetheless, we found significant improvement in processing speed in the group that received tablet training. What remains to be seen is whether this improvement would transfer to other cognitive domains given longer intervention durations. For example, the ACTIVE study incorporated three different types of cognitive training interventions: memory, reasoning, and processing speed. Although all three interventions improved the trained cognitive ability, results suggested that improvements did not transfer to other cognitive abilities.[32]

In the Tablet for Healthy Ageing study, we ran the classes in community-based settings (i.e., libraries). The program consisted of a structured curriculum organized by topics and related apps. It also consisted of home-based activities that encouraged participants to interact with the tablets, and discover new apps and explore the potential uses of the tablets that were personally interesting and relevant. A tablet intervention focuses on lifestyle engagement, and therefore could be easily incorporated in community-based settings and extended at home-based settings. It could also be cost-effective, as Czaja and colleagues[33] found that community-based computer programmes can be effectively delivered by volunteers.

We should note that our study used a control group that was not involved in any kind of activity. Therefore, significant differences between the two groups may be due to other factors, such as social interaction in the tablet group. Future studies should include a receptive engagement group that will participate in activities with low cognitive demands to quantify the cognitive benefit attributable to the increased social interaction versus the new learning activities. Our findings may also not be applicable to older adults beyond 76 years old, and therefore future studies should investigate whether our results could be replicated beyond that age. In addition, although participants had no tablet experience, the majority had some computer experience, and therefore their prior computer experience may have impacted on their level of cognitive engagement. Future studies should involve less technology-experienced participants to allow comparison of the benefits that might be derived in more versus less naïve users.

In summary, the purpose of the tablet intervention was to engage community-dwelling healthy older adults with a new mentally challenging activity and investigate the impact of this on short-term changes in cognitive function. Participants who were tablet novices learned how to use a tablet and through various apps became involved in a variety of activities and used a number of services. We found that the intervention improved Processing Speed in participants in the tablet intervention group compared with a control group. In addition, tablet participants mastered a new technology that may have the potential to facilitate certain activities in their day-to-day lives (online banking, social networking, etc.). Further investigation is required to confirm these results in longer-term follow-ups, and whether gains in certain cognitive domains might translate to increased independence and improved quality of life in older adults as previous studies have suggested.[32] Although the principal aim was to examine cognitive engagement and cognitive aging, examining interventions in the "real-world" affords opportunities to better understand how any cognitive benefits might transfer to other life outcomes of importance to older adults.

This work was supported by The Dunhill Medical Trust (R359/0514) to A.J.G. and M.M.

An early version of the results were presented at the Researcher Links workshop "Ageing and Health—How To Get There?", Sao Paulo, Brazil, funded by the Newton Fund and British Council to E.V., and the Cognitive Aging Conference 2016, Atlanta, GA, USA, conference costs part funded by The Royal Society of Edinburgh and Guarantors of Brain to A.J.G.

A.J.G. is a member of The University of Edinburgh Centre for Cognitive Ageing and Cognitive Epidemiology, part of the cross council Lifelong Health and Wellbeing Initiative (MR/K026992/1). Funding from the BBSRC and MRC is gratefully acknowledged.

We thank Professor Denise Park for allowing access to the tablet intervention protocol described in Chan et al.,[15] that formed the basis of the Tablet for Healthy Ageing study. We also thank Professor Park for useful comments on drafts of the manuscript.

None of the authors have relevant financial interests, activities, relationships, affiliations, or other potential conflicts of interest to report.

APPENDIX: SUPPLEMENTARY MATERIAL

Supplementary data to this article can be found online at doi:10.1016/j.jagp.2016.11.015.

References

1. World Health Organization: Global health and ageing. 2011
2. Bárrios H, Narciso S, Guerreiro M, et al: Quality of life in patients with mild cognitive impairment. Aging Ment Health 2013; 17:287–292
3. Adler NE: Community preventive services. Am J Prev Med 2003; 24:10–11
4. Hertzog C, Kramer AF, Wilson RS, et al: Enrichment effects on adult cognitive development can the functional capacity of older adults be preserved and enhanced? Psychol Sci Public Interest 2008; 9:1–65
5. Ackerman PL, Kanfer R, Calderwood C: Use it or lose it? Wii brain exercise practice and reading for domain knowledge. Psychol Aging 2010; 25:753–766
6. Park DC, Gutchess AH, Meade ML, et al: Improving cognitive function in older adults: nontraditional approaches. J Gerontol B Psychol Sci Soc Sci 2007; 62(special 1):45–52
7. Schultz S, Larson J, Oh J, et al: Participation in cognitively-stimulating activities is associated with brain structure and cognitive function in preclinical Alzheimer's disease. Brain Imaging Behav 2014; 9:729–736

8. Valenzuela MJ, Sachdev P, Wen W, et al: Lifespan mental activity predicts diminished rate of hippocampal atrophy. PLoS ONE 2008; 3:e2598
9. Gow AJ, Corley J, Starr JM, et al: Reverse causation in activity–cognitive ability associations: the Lothian Birth Cohort 1936. Psychol Aging 2012; 27:250–255
10. Salthouse TA, Berish DE, Miles JD: The role of cognitive stimulation on the relations between age and cognitive functioning. Psychol Aging 2002; 17:548–557
11. Tranter LJ, Koutstaal W: Age and flexible thinking: an experimental demonstration of the beneficial effects of increased cognitively stimulating activity on fluid intelligence in healthy older adults. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn 2008; 15:184–207
12. Stine-Morrow EAL, Parisi JM, Morrow DG, et al: The effects of an engaged lifestyle on cognitive vitality: a field experiment. Psychol Aging 2008; 23:778–786
13. Carlson MC, Saczynski JS, Rebok GW, et al: Exploring the effects of an "everyday" activity program on executive function and memory in older adults: Experience Corps. Gerontologist 2008; 48:793–801
14. Park DC, Lodi-Smith J, Drew L, et al: The impact of sustained engagement on cognitive function in older adults: the Synapse Project. Psychol Sci 2013; 25:103–112
15. Chan MY, Haber S, Drew LM, et al: Training older adults to use tablet computers: does it enhance cognitive function? Gerontologist 2016; 56:475–484
16. Mynatt ED, Rogers WA: Developing technology to support the functional independence of older adults. Ageing Int 2001; 27:24–41
17. We are social: global digital statistics 2014. http://etonpreneurs.com/uploads/Global%20Social,%20Digital%20&%20Mobile%20Statistics,%20Jan%202014.pdf
18. Goodman LA: Snowball sampling. Ann Math Stat 1961; 32:148–170
19. Folstein MF, Folstein SE, McHugh PR: Mini-Mental State: a practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975; 12:189–198
20. Zigmond AS, Snaith RP: The hospital anxiety and depression scale. Acta Psychol (Amst) 1983; 67:361–370
21. Nelson HE, Willison J: National Adult Reading Test (NART). Windsor: Nfer-Nelson, 1991
22. World Health Organization: Development of the World Health Organiization WHOQOL-BREF quality of life assessment. Psychol Med 1998; 28:551–558
23. National Health Service Scotland: Warwick-Edinburgh Mental Well-being Scale (WEMWBS). University of Warwick and University of Edinburgh, 2006
24. Wechsler D: WAIS-IV UK Administration and Scoring Manual. London: Pearson, 2010
25. Vaportzis E, Giatsi Clausen M, Gow AJ (under review): Older adults perceptions of technology and barriers to interacting with tablet computers: A focus group study. *Comput Human Behav*
26. Ball K, Berch DB, Helmers KF, et al: Effects of cognitive training interventions with older adults: a randomized controlled trial. JAMA 2002; 288:2271–2281
27. Blom G: Statistical Estimates and Transformed Beta Variables. New York: Wiley, 1958
28. Salthouse TA: The processing-speed theory of adult age differences in cognition. Psychol Rev 1996; 103:403–428
29. Yaffe K, Fiocco A, Lindquist K, et al: Predictors of maintaining cognitive function in older adults: the Health ABC Study. Neurology 2009; 72:2029–2035
30. Brandt J: The Hopkins Verbal Learning Test: development of a new memory test with six equivalent forms. Clin Neuropsychol 1991; 5:125–142
31. Robbins TW, James M, Owen AM, et al: Cambridge Neuropsychological Test Automated Battery (CANTAB): a factor analytic study of a large sample of normal elderly volunteers. Dement Geriatr Cogn Disord 1994; 5:266–281
32. Wolinsky FD, Unverzagt FW, Smith DM, et al: The effects of the ACTIVE cognitive training trial on clinically relevant declines in health-related quality of life. J Gerontol B Psychol Sci Soc Sci 2006; 61:S281–S287
33. Czaja SJ, Lee CC, Branham J, et al: OASIS connections: results from an evaluation study. Gerontologist 2012; 52:712–721